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Confidence Ratings and Message Reception for Filtered Speech

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THE statistical decision model of signal detection has enjoyed outstanding success in describing an operator's performance in detecting sinusoidal

signals in noise.¹ The decision model has been extended to the recognition of one out of several signals in noise² and to the identification of supra-threshold signals in

¹ Tanner, Swets, and Green, "Some general properties of the hearing mechanism," Electronics Defense Group Technical Report No. 30, Engineering Research Institute, University of Michigan, March, 1956, and references cited therein.

² W. P. Tanner, Jr., *J. Acoust. Soc. Am.* **28**, 882-888 (1956).

noise.³ The model has also been successfully extended to the identification of spoken messages in noise.⁴

The success of the model is not entirely unexpected. The decision model requires a discrimination between two processes: one reflecting Gaussian properties of noise alone and the other reflecting Gaussian properties of the signal plus noise. These two processes are represented upon a single decision continuum. Partitioning of the continuum yields the ROC curve, or the Receiver Operating Characteristic, which describes a relation between the probability of a correct confirmation and the probability of a false alarm.

Because of the tremendous simplification gained by employing Gaussian distributions in the decision model, we are necessarily reluctant to abandon the simplified model even in experiments *without* noise interference. If successful application of the model could be achieved for the "noise-free" experiment, the generality of the model might be extended. "Noise" of the statistical model might, then, represent a wide class of operations which perturb the signal.

In the present study, low-pass filtering is employed as a method of signal interference to test the extension of the model to message reception in the "noise-free" experiment.

We shall test the generality of the model in conjunction with a rating procedure employed in a previous study.⁵ A speech signal, subjected to low-pass filtering is presented to our listener. He has two tasks: he must identify the word from a closed message set and he must assign a rating reflecting his judged accuracy of having received the message correctly. The rating procedure permits treatment of the data in the same manner as a binary-decision procedure of message acceptance and message rejection at fixed decision levels.

In conjunction with the rating procedure and filtered speech, we asked two questions:

1. Does the rating procedure with filtered speech yield ROC curves previously observed with message reception in noise?
2. Is a simple consistent relation between message reception and accuracy ratings, previously observed over a range of noise levels, obtained over a range of filtering levels?

PROCEDURE

The rating procedure, testing equipment, experimental subjects, and test procedures were identical with the previous study with the following exceptions: a sharp cutoff filter (Gertsch SA-2) replaced the noise source as the method for interfering with the speech materials; a lower speech level, 60 db re 0.0002 dyne/cm²,

³ W. P. Tanner, Jr., J. Acoust. Soc. Am. 29, 766(A) (1957).

⁴ J. P. Egan, "Message repetition, operating characteristics, and confusion matrices in speech communication," Technical Report AFCRC TR 57-50, AD 110,064, Hearing and Communication Laboratory, Indiana University, June, 1957, and references cited therein.

⁵ I. Pollack and L. Decker, J. Acoust. Soc. Am. 30, 286 (1958).

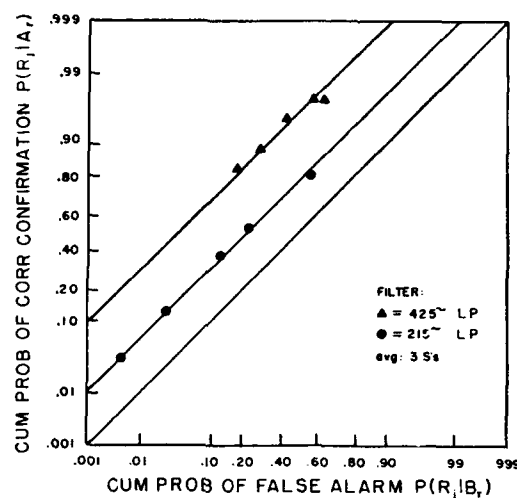


FIG. 1. The Receiver Operating Characteristics at two filtering levels. The abscissa is the cumulative probability that the listener was willing to state (in terms of his confidence judgment) that he correctly received the message when in fact, he failed to receive it correctly. The ordinate is the cumulative probability that the listener was willing to state that he correctly received the message when, in fact, he did receive it correctly. The parameter is the low-pass cutoff frequency. Each curve is based upon 1350 observations per listener for three listeners.

was employed to insure effectiveness of filtering and one of the listeners of the old testing crew was replaced by a new listener.

After completion of extensive tests with the identification of words in noise, a total of 4 test sessions, each approximately 2 hours in duration, was devoted to training with frequency-limited speech. Each test consisted of 75 spondee words, each chosen from two replications of a class of 64 spondee words. The average percentage of words correctly received associated with low-pass cutoff frequencies of 212 cps and 425 cps was 15.2% and 90.0% correct, respectively.

RESULTS

Our first question was: *Does the rating procedure yield ROC curves with filtered speech?* Apparently yes. The results are presented in Fig. 1.

The ordinate of Fig. 1 represents the probability that a listener was willing to state (in terms of his confidence judgment) that he had received the message correctly, when, in fact, he had received it correctly; the abscissa represents the probability that a listener was willing to state that he had received the message correctly, when, in fact, he failed to receive it correctly. In signal detection terms, the ordinate represents the probability of a correct confirmation; the abscissa represents the probability of a false alarm. The separate points represent separate confidence levels. The parameter on the curves is the low-frequency cutoff.

The diagonal 45° line represents chance performance. A slope of 1.0 indicates that, in the decision model of message reception, the variances of the perturbation and the message-plus-perturbation distributions are equal.

The ROC curves of Fig. 1, yielded by the rating

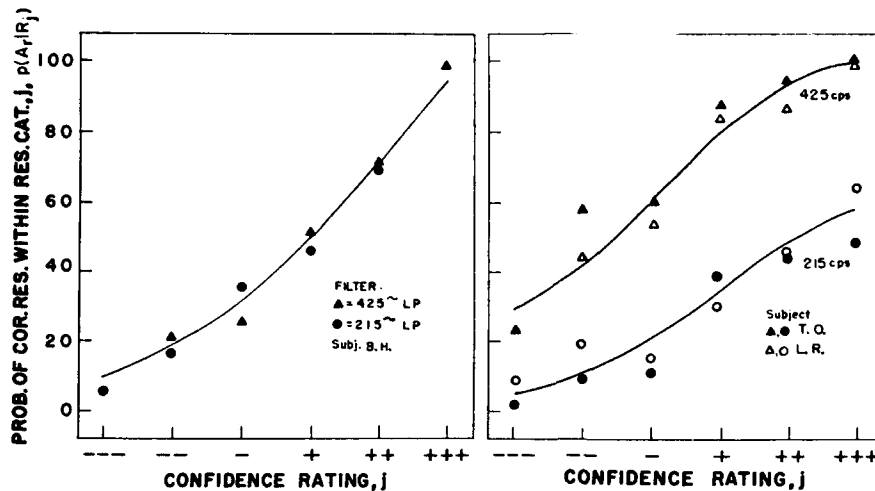


FIG. 2. The probability of a correct message reception within given rating categories at two filtering levels. The abscissa is the confidence rating of accuracy of message reception. The ordinate is the proportion of correct message receptions of the total responses assigned each rating category. Alternative presentation of results of Fig. 1.

procedure with filtered speech, are linear functions drawn upon double probability axes. In addition, the slope of the curves is 1.0. These two properties, exhibited with noise interference, demonstrate the applicability of the statistical decision model. The results, thus, suggest that any functional perturbation of the signal may be profitably represented in terms of "noise" of the statistical decision model.

The second question was: *Is a simple consistent relation between message reception and accuracy ratings obtained over a range of filtering levels?* Possibly. The results are presented in Fig. 2.

The abscissa of Fig. 2 is the listener's confidence rating, ranging from --- ("My received message is a blind guess") to +++ ("I am positive that I received the message correctly"). The ordinate is the percentage of words, within each of the assigned confidence ratings, that were correctly received. The parameter is the low-pass frequency cutoff. The individual subjects are represented by coding *within* the points.

If listeners adopt the strategy of assigning confidence criteria on the basis of fixed average levels of message reception, irrespective of the degree of filtering, the two curves would be superimposed. That they are not superimposed, suggests that our listeners operated with a different strategy when faced with the two filtering conditions.

One of our listeners, whose results are presented on the left side of Fig. 2, yielded results which closely approximate the consistent relation previously observed (Figs. 5 and 6 of reference 5). The other two listeners (including the new listener) tended to employ their rating categories differently under the two filtering levels. Their results are presented on the right side of Fig. 2. In terms of the average listener, the results of

Fig. 2 suggest that listeners may switch from the previously noted strategy when faced with different filtering conditions.

With the hindsight of experience, the results of Fig. 2 are not unreasonable. In the previous study, the qualitative features and the average intelligibility associated with the three speech-to-noise ratios were not markedly different. However, in the present study, both the qualitative features and the average intelligibility associated with the two filtering levels were markedly different. And, apparently, when faced with the markedly different filtering situations, two of our listeners readjusted their rating categories with filtering level.

DISCUSSION

The equivocal status of the relation between rating categories and accuracy of message reception, observed to be consistent over a range of speech-to-noise ratios (previous paper), but not with two filtering conditions (present paper), should not negate the primary point of this study. Namely, the conceptual decision model, which is essentially a Gaussian model representing the discrimination between a "noise" and a "signal plus noise" process, may be applied to a "noise-free" listening condition—here, to filtered speech. To this extent, the results suggest an extension of the concept of "noise" in the decision model to a variety of operations which perturb the signal.

This point of view is not unreasonable. The basic statistical model is essentially a model for the resolution of uncertainty regardless of how the uncertainty is produced. We venture to guess that any operation upon the signal, which results in response uncertainty, will yield decision relationships of the same general type.